E/CONF.39/A/196
29 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A.3.1.2

Australia

THE ORGANIZATION OF METEOROLOGICAL SERVICES FOR HYDROLOGY

By A.F. RAINBIRD,
Commonwealth Bureau of Meteorology,
Melbourne, Australia

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

THE ORGANIZATION OF METEOROLOGICAL SERVICES FOR HYDROLOGY

by

A.F. RAINBIRD
Commonwealth Bureau of Meteorology
Melbourne, Australia

1. Water is redistributed continually on the earth's surface through the complex interaction of the physical processes governing the so-called "hydrological cycle", in which the earth's atmosphere plays a basic role. The various distinct processes which combine to govern the "hydrological cycle", precipitation, evaporation, runoff, infiltration etc., are interdependent. As the behaviour of the atmosphere directly influences the net supply (balance between precipitation and evaporation) of water to a particular land area, and the variability of that supply with time, hydrologists can increase the efficiency of water resources development and management practices through use of meteorological services. They are most frequently concerned with river behaviour, for it is rivers that provide the most accessible supply of water. The present discussion will therefore be confined to the application of meteorological services to streamflow assessment and management.

NATURE OF METEOROLOGICAL SERVICES REQUIRED

2. Two principal tasks confront hydrologists - the assessment and development of the water resources of a nation, region or river basin, and the subsequent management and operational use of the available resources in the most beneficial manner.

3. Assessment and development problems are of a non-repetitive nature, their solution is not geared to a rigid timetable, and there is no necessity to determine the exact time sequence of estimated future hydrological events. On the other hand, operational problems are of a continuing nature, they require forecasts of streamflow, and hence of those atmospheric processes which influence streamflow, and analysis of the current hydrological situation must be completed in a minimum of time.[2]

4. Many problems of assessment could be readily solved if a long period record of good quality streamflow data were available. Frequently it is not and the expected streamflow experience may have to be estimated from the observed or estimated variability, in time and space over the drainage system, of the other major, interdependent elements of the "hydrological cycle" such as precipitation depth and intensity, evaporation and soil moisture (or other suitable index of a catchment's "wetness" or effectiveness in producing surface runoff from a particular storm rainfall). The main contribution of meteorological services thus lies in the collection, collation and analysis of observations within the river basin or area of interest, of those meteorological elements exercising a major influence on the "hydrological cycle" of the basin; according to Kohler,[2] these are precipitation (depth and intensity), snow cover, air temperature, humidity, wind, evaporation, radiation, soil moisture, soil temperature, frost penetration.

5. Operational use of water resources frequently calls for the forecasting of streamflow to be expected during a specified period, such as the following 24 or 48 hours. In river basins where storm runoff concentrates rapidly in streams, flood waves frequently travel so rapidly through the drainage system that, in order to provide effective advance warning, streamflow must be forecast from frequent observations of rainfall depth or forecasts of it or from these observations and forecasts combined. The main contribution of meteorological services lies in the forecasting of the expected onset and cessation of heavy rainfall (this may allow advance action to be taken, such as the draw-down of water levels in storage reservoirs etc), the rapid collection and analysis of frequent rainfall observations during a storm and the forecasting of the most probable depth of rain likely to fall during all or part of the further duration of a storm.

DESIGN OF HYDROMETEOROLOGICAL NETWORKS

6. Instrument networks must be established to obtain hydro-

meteorological data, to provide a basis of experience from which the long term streamflow behaviour might be estimated and to provide observations for operational forecasting of streamflow. In planning hydrometeorological networks it is important to recognize that streamflow is one component of the water balance of a river basin, others being precipitation, evaporation and storage (of water within the river basin). Interpretation of short-period records of one component is more reliable if there are concurrent observations of the others.

7. To the extent permitted by available resources, co-ordinated instrument networks should be established which will permit a detailed study to be made of the complete water balance of the region, river basin or sub-basin under investigation. Kohler[2] has listed the types of observations which should be made. In addition to "point"observations at a number of stations within each basin or sub-basin of the elements listed in paragraph 4, the following river observations should be made at the basin or sub-basin outlet: discharge, sediment, water quality, water temperature, ice thickness.

8. Some types of observations such as those of rainfall depth, are relatively inexpensive except in uninhabited areas, while others such as stream discharge and radiation, may require quite costly instrumentation. The density of the instrument network to be established is an important question as it affects the capital cost of instrument procurement and installation and annual cost of maintenance and reading of instruments. Numerous writers, such as Linsley,[3] have discussed network densities and the problem is being studied by expert bodies such as the Technical Commission for Hydrological Meteorology of the World Meteorological Organization.

9. There is probably no general prescription for instrument network design which will satisfy all possible data requirements, but Langbein,[4] has suggested a useful basic principle. Recognizing that the time (optimum period of years for which a gauge should be operated) and space (optimum spacing of gauges in a network) aspects of network design cannot be independently evaluated, Langbein proposes the establishment of a firm network of base stations to serve as fixed points for the time sampling factor and a group of secondary stations to be operated for relatively short periods to cover the space sampling factor.

10. If a network is to be established progressively over several years, base stations should be established first to obtain the maximum length of record from available resources. In the selection of base stations, it is desirable to place instruments at sites where they can receive regular maintenance and performance can be checked at frequent intervals. This checking is particularly important as much valuable data are lost through faulty operation of instruments which have not received adequate maintenance and attention. Where instruments have to be installed at uninhabited sites, they should be inspected as frequently as is possible.

11. There are several advantages to be gained through establishment of a unified control over the planning and operation of hydrometeorological instrument networks. In the planning phase, a single responsible authority is able to consider the various purposes to be served by the network within a region or river basin and can plan a co-ordinated network to observe all related components of the regional or basin water balance most efficiently and economically. There are obvious savings to be achieved if field parties under a single control are responsible for operation and maintenance of all instruments. It is more efficient and economical if a single authority collects and publishes data; it is also more convenient, for access, if it holds the unpublished data.

12. National Meteorological Authorities normally establish and organize extensive data collection networks, and in regions where establishment of co-ordinated hydrometeorological instrument networks is not the responsibility of other authorities, adoption of this function by the Meteorological Authority may be the most efficient and cheapest solution.

MACLEAY RIVER VALLEY - EASTERN AUSTRALIA

13. Hydrometeorological studies carried out for the Macleay River Valley of eastern Australia illustrate an application of meteorological services to hydrological problems. The Macleay River basin (4150 sq miles), on the North Coast of New South Wales, drains

eastward to the Pacific Ocean from the Great Dividing Range about 100 miles inland. About one half of the area has been cleared for grazing and agricultural pursuits; 300 sq miles of this forms a broad flood plain near the river's outlet. The town of Kempsey (population 8000) is some 20 miles upstream from the river outlet and both Kempsey and the agriculturally rich flood plain below it are subjected to flooding at irregular intervals.

14. The Macleay River at Kempsey rises very rapidly following heavy rainfall over the catchment area. In the record flood of August 1949 flow increased from 2000 cubic feet per second (cusecs) to about 500,000 cusecs in 24 hours. Local authorities at Kempsey requested development of a flood forecasting system for the lower Macleay Valley and this work was undertaken by the Bureau of Meteorology.

15. Flood Forecasting System. The flood forecasting system has been developed[5] to provide a minimum of 24 hours warning of the height and time of occurrence of a flood crest at Kempsey and a minimum of 12 hours warning of the time at which the river will spill over its banks onto the flood plain. The flood forecasting system is operated from a Forecast Centre located within the Bureau of Meteorology's New South Wales Divisional Office in Sydney, some 250 miles from the Macleay River Valley.

16. Each day reports of rainfall depth are telegraphed to the Forecast Centre from eight rainfall observing stations strategically located within the Macleay Valley. The current value of an index to catchment "wetness", or effectiveness in producing surface runoff from storm rainfall, which is based on antecedent precipitation over the catchment, is computed each day from the telegraphed rainfall reports.

17. At the Forecast Centre continuous meteorological watch is kept over the Macleay Valley and the rain producing potential of current and expected synoptic situations is assessed at regular intervals. Alerting messages are sent to rainfall and river height observers whenever it is expected that sufficient rain will fall on the catchment area to produce surface runoff at the prevailing condition of catchment "wetness". On receipt of alerting messages, observers report rainfall depths at eight observing stations and river heights at two observing stations (Kempsey and Bellbrook, the latter being approximately 50 miles upstream of Kempsey) at three hourly intervals until requested to cease observations.

18. To guard against situations in which heavy rain develops unexpectedly or more rapidly than anticipated, each of the eight rainfall reporting stations is equipped with a gauge which sounds an alarm when approximately one inch of rain is recorded. Observers empty the gauges each day at 9 a.m. and if the alarm sounds, indicating approximately one inch of rain since 9 a.m. and no alerting message has been received from the Forecast Centre, the observer immediately telegraphs a Heavy Rainfall Report to the Centre. On receipt of such a report, meteorologists at the Centre immediately assess the rain producing potential of the meteorological situation and decide whether to issue alerting messages to observers which will initiate regular three hourly observations of rainfall and river height. If the meteorological situation is uncertain, rainfall observations at stated times may be requested from one or more of the eight observers to assist in determining whether a general alerting advice is warranted.

19. When three hourly observations have been requested, hydrologists commence duty within the Forecast Centre and work in close co-operation with the meteorologists until the flood begins to subside or until danger of flooding passes. The streamflow forecasting methods developed[5] require three hourly estimates of the rainfall over the valley. In preliminary investigations,[6] catchment rainfall depths experienced in various storm situations were studied and eight rainfall stations were selected within the catchment, such that the arithmetic mean of depths observed at these eight stations was an acceptable approximation in all storm situations to the estimated mean rainfall depth over the entire catchment. The eight rainfall stations selected are those which now report rainfall depth each three hours after receiving an alerting advice.

20. Hydrologists predict streamflow at Kempsey, and hence expected river height at stated times, from the three hourly rainfall observations. When heavy rainfall concentrates over the lower reaches of the stream, that is in an around the Kempsey region, the river rises

very rapidly and sufficient warning cannot be obtained by predicting streamflow from observed rainfall alone. Meteorologists therefore forecast the mean depth of rainfall expected over the catchment during the following 6 to 9 hours. The expected "trend" of precipitation intensity is forecast, that is whether rainfall will be heavier, lighter or unchanged in intensity in the next 6-9 hours compared with the past 6-9 hours. Estimates of mean catchment rainfall depth during the past 6-9 hours are available and from these estimates and the forecast of precipitation intensity "trend", subjective estimates are made of likely mean depths during the following 6-9 hours.

21. River behaviour forecasts are made from the combined observed and forecast rainfall depths and are telegraphed to a local flood warning authority within the Macleay Valley. This local authority converts the Bureau's river forecast, which is for a stated point on the stream, into terms of expected depths and areas of flooding and issues particular warnings to all residents within threatened areas. The Bureau's forecasts are issued to the general public for their information through radio and television broadcasting channels and are issued to authorities concerned with flood rescue and relief to assist in the planning of their operations.

22. Communications. River forecasts must be available in Kempsey no later than one-and-one-half hours after the time of taking the rainfall observations on which the particular river forecast is based. Speedy and reliable communications, telegraphic and telephonic, have been arranged.

23. Automatic rain gauges which report by radio to a receiving station are being installed at three rainfall stations communications with which may be interrupted. The radio equipment can operate unattended for periods up to six months, using wind powered generators to recharge the battery units which power the transmitters. The ideal of complete control by a Flood Forecast Centre over its communications system is not possible in the Macleay Valley.

24. Hydrometeorological Instrument Network. There were twenty-six rainfall observing stations located within the catchment area of 4,150 sq miles when investigations were commenced. These stations were not evenly distributed throughout the river basin and provided a satisfactory gauging of rainfall for only 70% of the total area. The hydrometeorological instrument network within the catchment has been expanded to include: 50 daily read rain gauges, 10 pluviographs (including 5 long term instruments at unattended sites), 3 automatic, radio-reporting rain gauges, 7 stream level recorders (including one equipped for automatic reporting over a landline circuit), and 4 evaporimeters. No attempt has been made at present to establish base and secondary stations (paragraph 9). As additional data are collected, further investigations will be carried out to define more precisely the hydrometeorological characteristics; improved operational and general purpose data networks will then be determined and the instrument network be reduced to what is judged to be the optimum density. It may be possible also to place the automatic, radio-reporting rain gauges to greater advantage, perhaps in uninhabited areas ungauged in the past but from which data are now being collected through the 5 long term pluviographs.

25. Data Treatment. In developing river forecasting for the Macleay Valley, rainfall-runoff relationships had to be established for past storm events. The recording of all such data on punch cards greatly simplified the extraction and tabulation of required data for editing and analysis. Rainfall data for other Australian river catchments are being recorded similarly.

---

2 Kohler, M.A., Design of hydrological networks, W.M.O. Tech. Note 25, Geneva (1958).

3 Linsley, R.K., Techniques for surveying surface-water resources, W.M.O. Tech. Note 26 Geneva (1958)

4 Langbein, W.B., Inter.Assoc.Sc.Hydrology, Publ.38, Gen. Assem. Rome (1954)

5 Watson, B., The development of a flood forecasting system for the Macleay river at Kempsey, N.S.W, Bur. Met. Work. Pap. 59/2854, Melbourne (1962).

6 Rainbird, A.F., Determination of an operational rainfall reporting network, Bur. Met. Work. Pap. 60/2846, Melbourne (1960).

1336 E - Nov.1962 - 1,600